

Dry Gas Sealing Systems for Oil Sands Pumping Applications

Design Engineering Issues and Resolutions

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Outline

This presentation highlights:

- Dry Gas Sealing System
- Problems/issues
- Root cause identification
- Short and long-term engineering solutions



Shell Canada – Scotford Upgrader Background

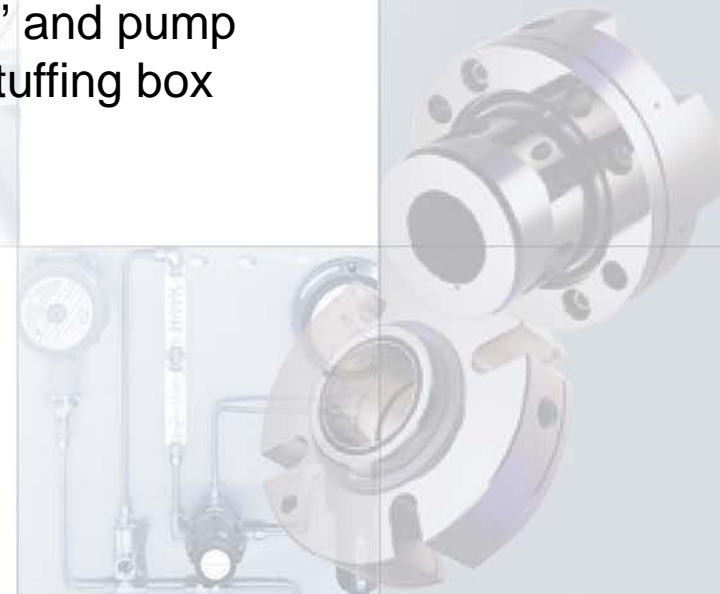
- Located next to Shell Canada's Scotford Refinery near Fort Saskatchewan, Alberta.
- Uses hydrogen-addition technology to upgrade the high viscosity “extra heavy” crude oil (called bitumen) from the Muskeg River Mine into a wide range of synthetic crude oils.

The Upgrader -- part of the joint venture project between Shell Canada, Chevron Texaco and Western Oil Sands – is operated by Shell Canada.



Shell Canada – Scotford Upgrader Background

- State-of-the-art Oil Sands Upgrader designed to process 155,000 BPD oil sands bitumen.
- The facility has a total of 95 Type 2800 Dry Gas Seals in various pumping applications.
- The horsepower of the pumps vary from 25 HP to 2500 HP.
- The size of the seals range from 2.0" to 6.5" and pump speeds vary from 1180 to 3600 RPM with stuffing box pressures between 200 and 3500 kPa.
- Both horizontal and vertical applications



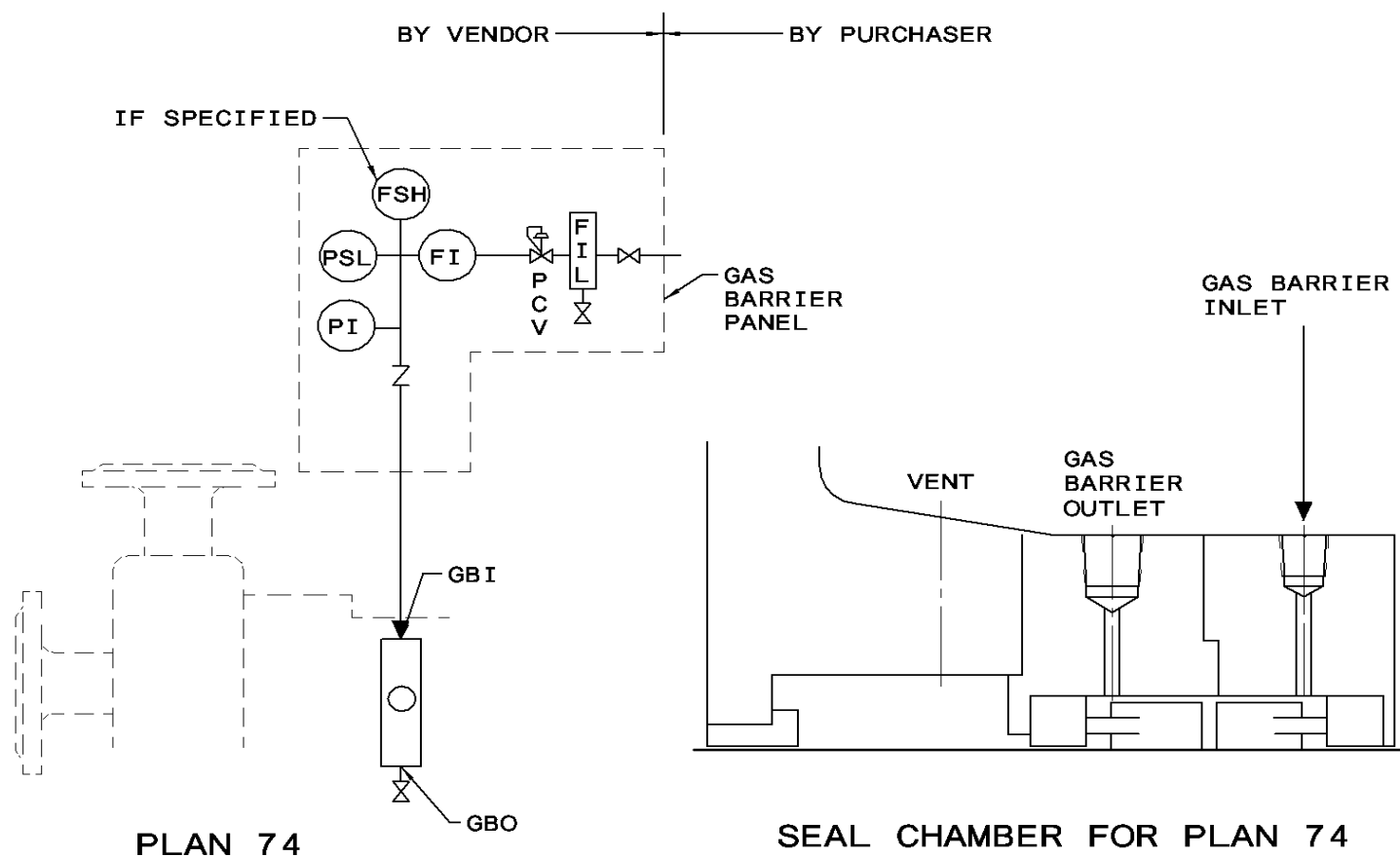
Shell Canada – Scotford Upgrader Background



At full production, the Muskeg River Mine will produce 155,000 barrels per day (bpd) of heavy crude oil, which, after upgrading, is ready for refining.

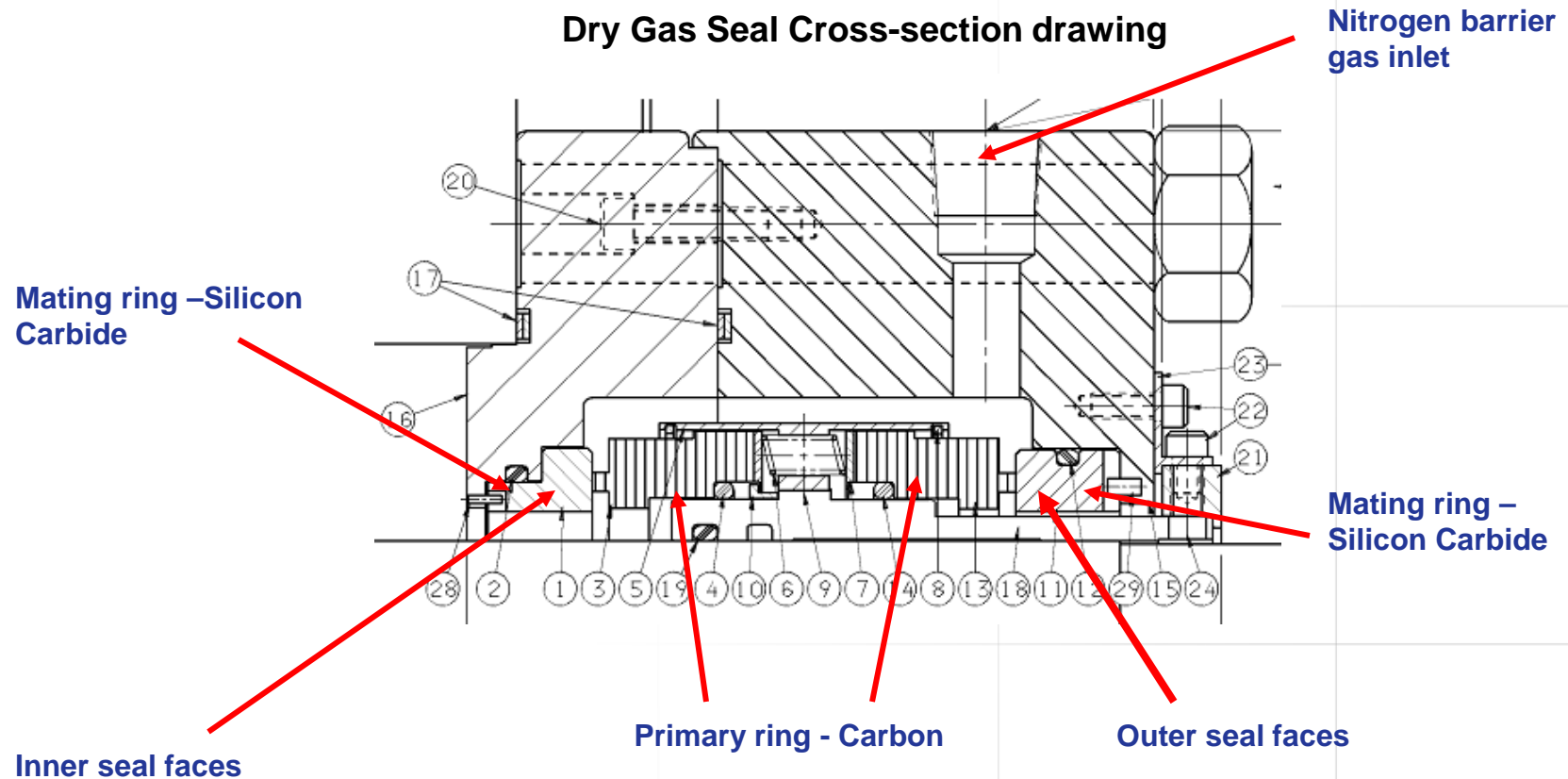
- Upgrading is the process of breaking large hydrocarbon molecules (such as bitumen) into smaller ones by increasing the hydrogen to carbon ratio.
- These upgraded crude oils are suitable feed stocks for refineries, which will process them into refined products like gasoline.
- Scotford's upgrading process adds hydrogen to the bitumen, breaking up the large hydrocarbon molecules (called hydrogen-addition or hydrogen-conversion).

Seal Flush Plan 74



Dry Gas Seal & Supporting System

Dry Gas Seal arrangement for zero-emission, zero-leak environment



Dry Gas Seal & Supporting System

Nitrogen gas panel provides:

- Filtration of buffer gas
- Regulation of buffer gas
- Monitoring of seal gas consumption
- Monitoring seal face temperatures through Resistance Temperature Detection Sensors (RTDs)
- Local indication of filter and seal performance

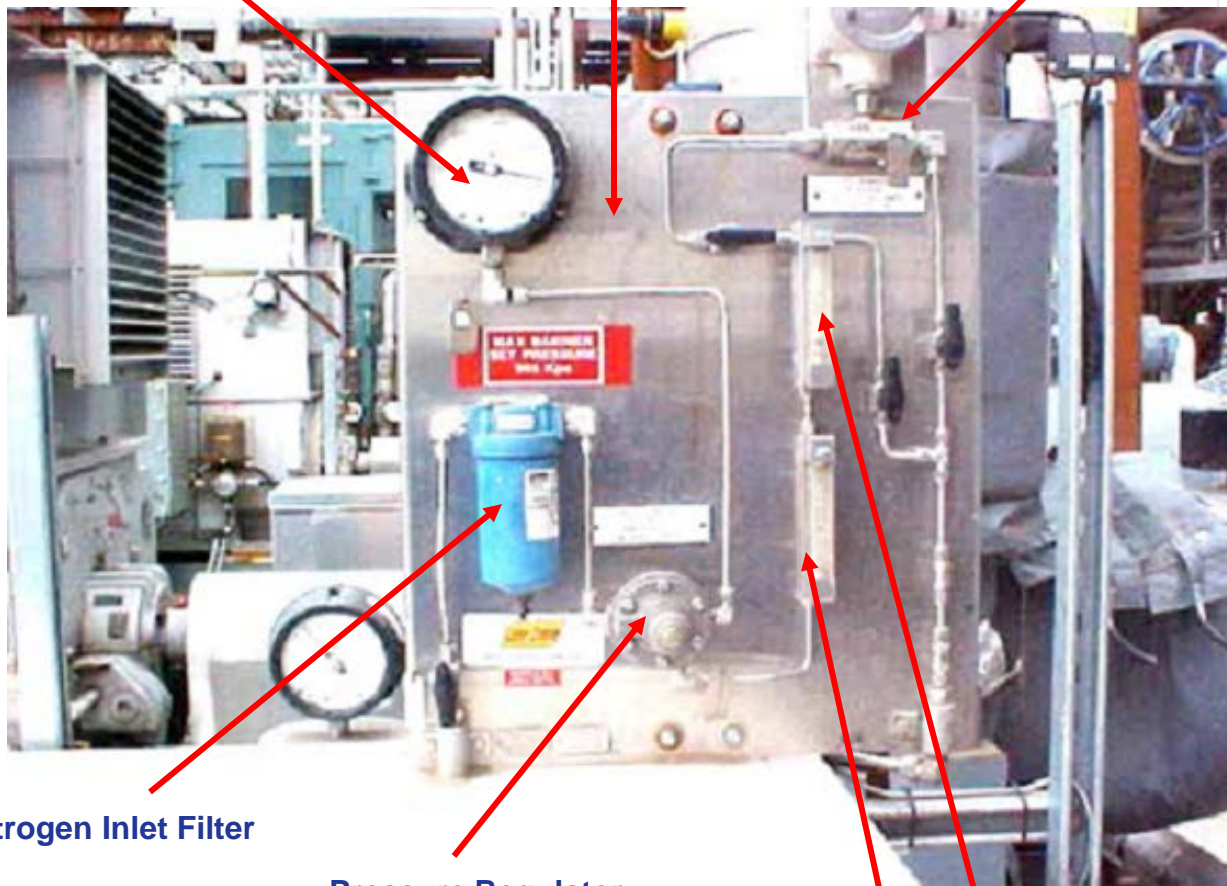


Dry Gas Seal & Supporting System

N2 Supply Pressure
to stuffing box

Local Nitrogen Gas Panel

Turbine Flow Meter

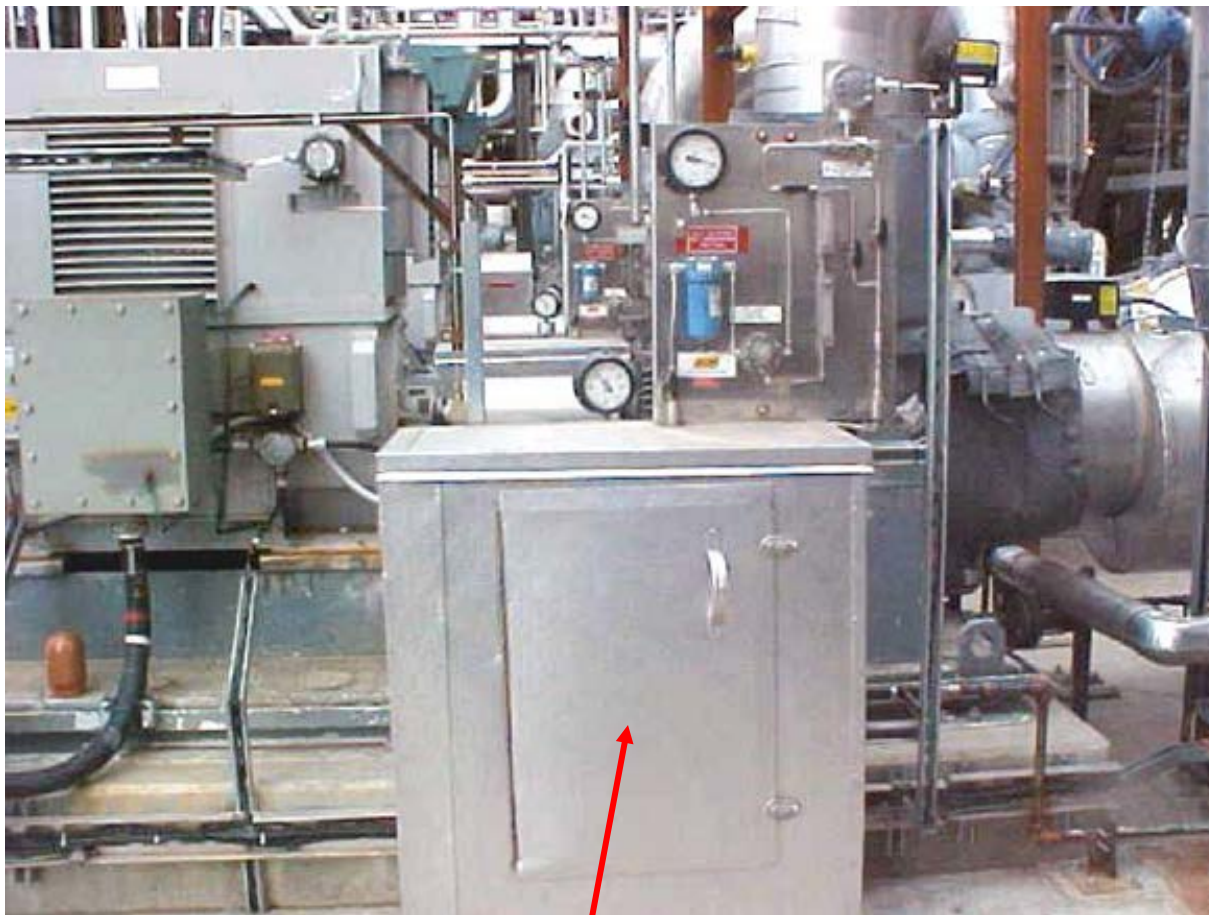


Nitrogen Inlet Filter

Pressure Regulator

Local Flow Indicators

Dry Gas Seal & Supporting System



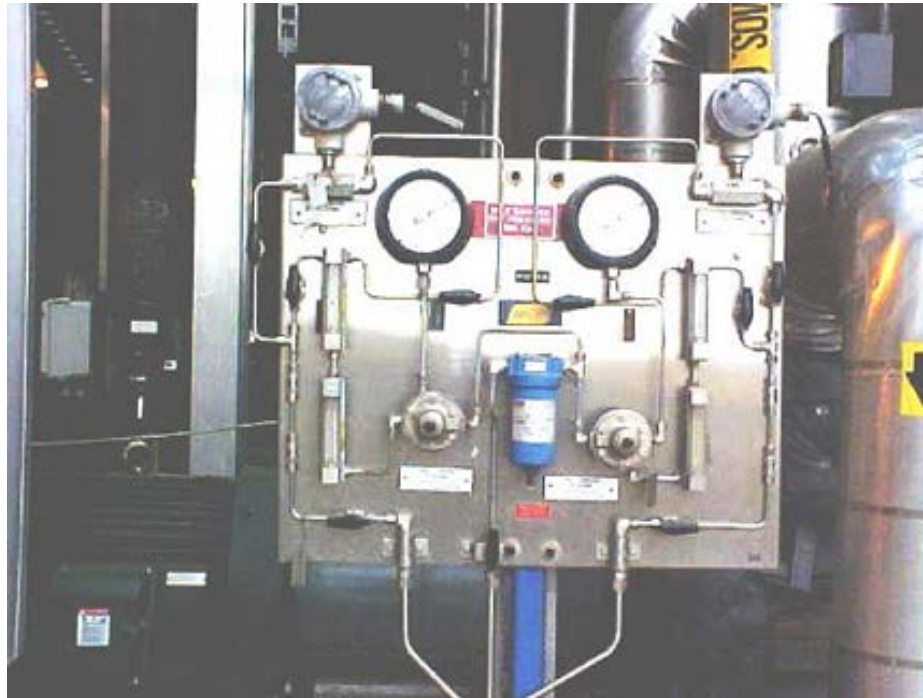
Nitrogen Booster (Insulated) Box

Dry Gas Seal & Supporting System



Nitrogen Booster

Dry Gas Seal & Supporting System



Gas Control Panel for Between Bearing Pump

Design Engineering Issues and Resolutions

The Initial engineering commissioning issues encountered are:

- Nitrogen gas supply pressure fluctuation issues
- Nitrogen gas contamination issues
- Nitrogen flow turbine meter commissioning failures
- Nitrogen boosters over-cycling issues
- Dry Gas Seal failures as a result of low ambient temperature ($< -7^{\circ}\text{C}$)
- Dry Gas Seal failures in VFD pumping applications
- Dry Gas Seal failures in series pumping applications
- Dry Gas Seal, coincident with pump failures in vertical in-line pumps

Design Engineering Issues and Resolutions

Seal Repairs at a Glance

- Total Dry Gas Seals on site: 95
- Total Dry Gas Seals repaired (before modification): 52
- Total Dry Gas Seals repaired (after modification): 28



Nitrogen Gas Supply Pressure Fluctuations Issues

Low nitrogen buffer gas pressure caused by unexpected interruptions by external supplier Leading to alternate crisis management solutions (i.e., truck and/or bottle connections). Supply pressure varies from 600 kPa (90 PSI) to 1100 kPa (165 PSI).

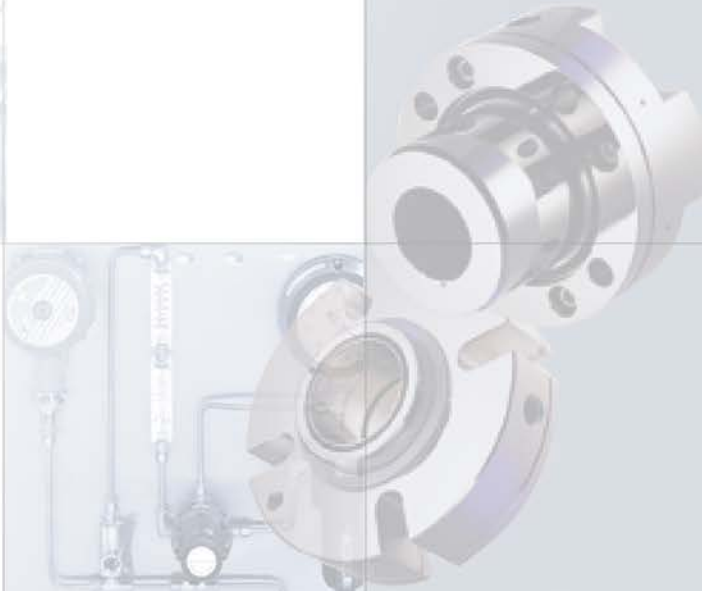
- Type 2800 Dual Dry Gas Seals are designed to operate at Vacuum to 2070 kPag
- Type 2800 HP Dual Dry Gas Seals are designed to operate at Vacuum to 4138 kPag



Nitrogen Gas Supply Pressure Fluctuations Issues

Recommendations for Success:

- Provide seal designer with clear nitrogen gas supply conditions.
- Develop alternate nitrogen supply piping connection



Nitrogen Gas Supply Contamination Issues

Nitrogen supplied through external source to Dry Gas Seals contaminated with water and pipe rust, causing the filters to plug and the filter cartridges to rupture and the seals to flood with water and debris.



Nitrogen Gas Supply Contamination Issues

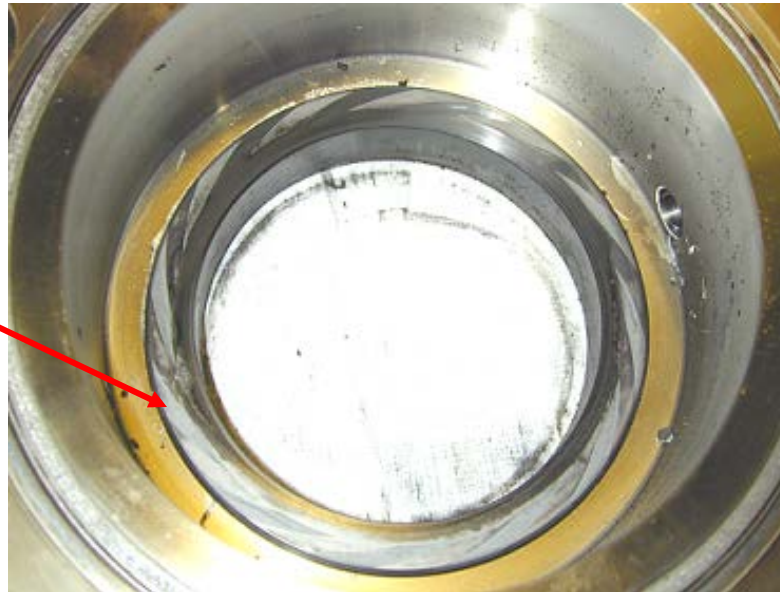
Recommendation:

- Proper nitrogen line flushing (remove filter cartridge & Flow meter during flushing)
- Install dual filter with DP gauge, and provision for on-line filter cartridge replacement



Nitrogen Gas Supply Purity Issues

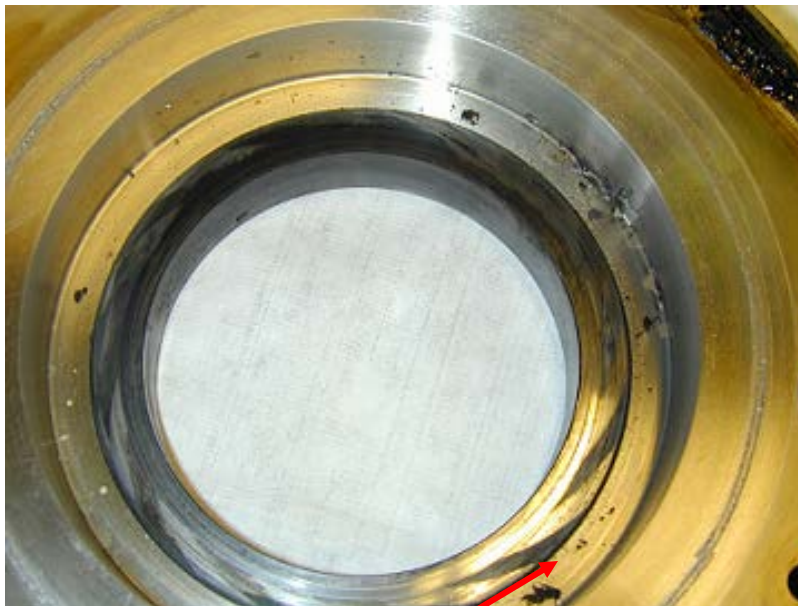
Outboard mating ring
and seal chamber
with debris



John Crane Root Cause Failure Analysis Report

- *Seal did not exhibit any signs of serious face contact.*
- *Tremendous amount of debris inside the seal chamber foreign to any material used in the seal.*
- *Source of contamination was the nitrogen supply system.*

Nitrogen Gas Supply Purity Issues



Inboard mating ring & seal chamber with debris

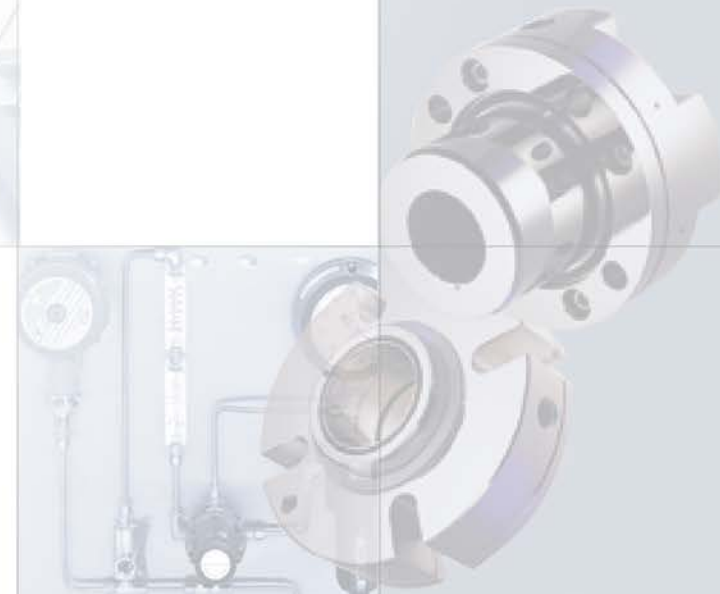


Foreign debris from nitrogen supply system

Nitrogen Flow Measuring Turbine Meter Commissioning Issues

During seal panel commissioning, panel piping was flushed by nitrogen serving to keep the drain open at seal stuffing box, causing:

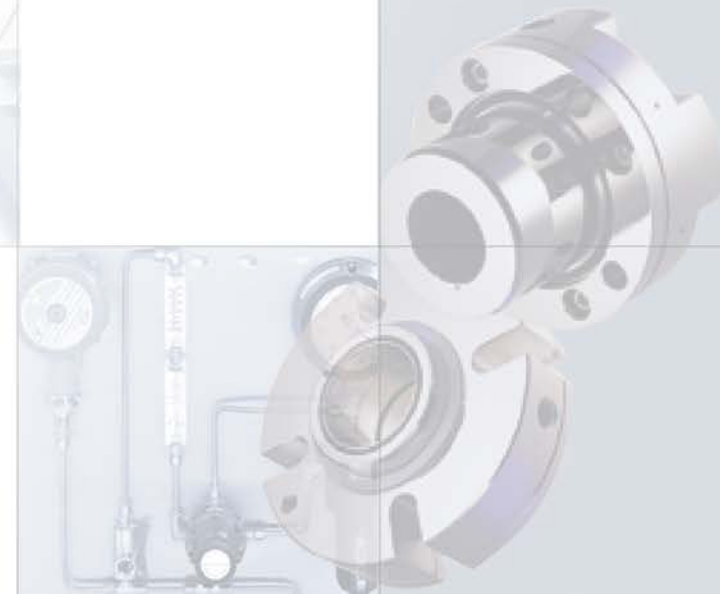
- turbine meter to over-spin due to higher flows (max flow 30 SCFH)
- damage to 60 flow meters at a repair cost of \$150,000 CAD.



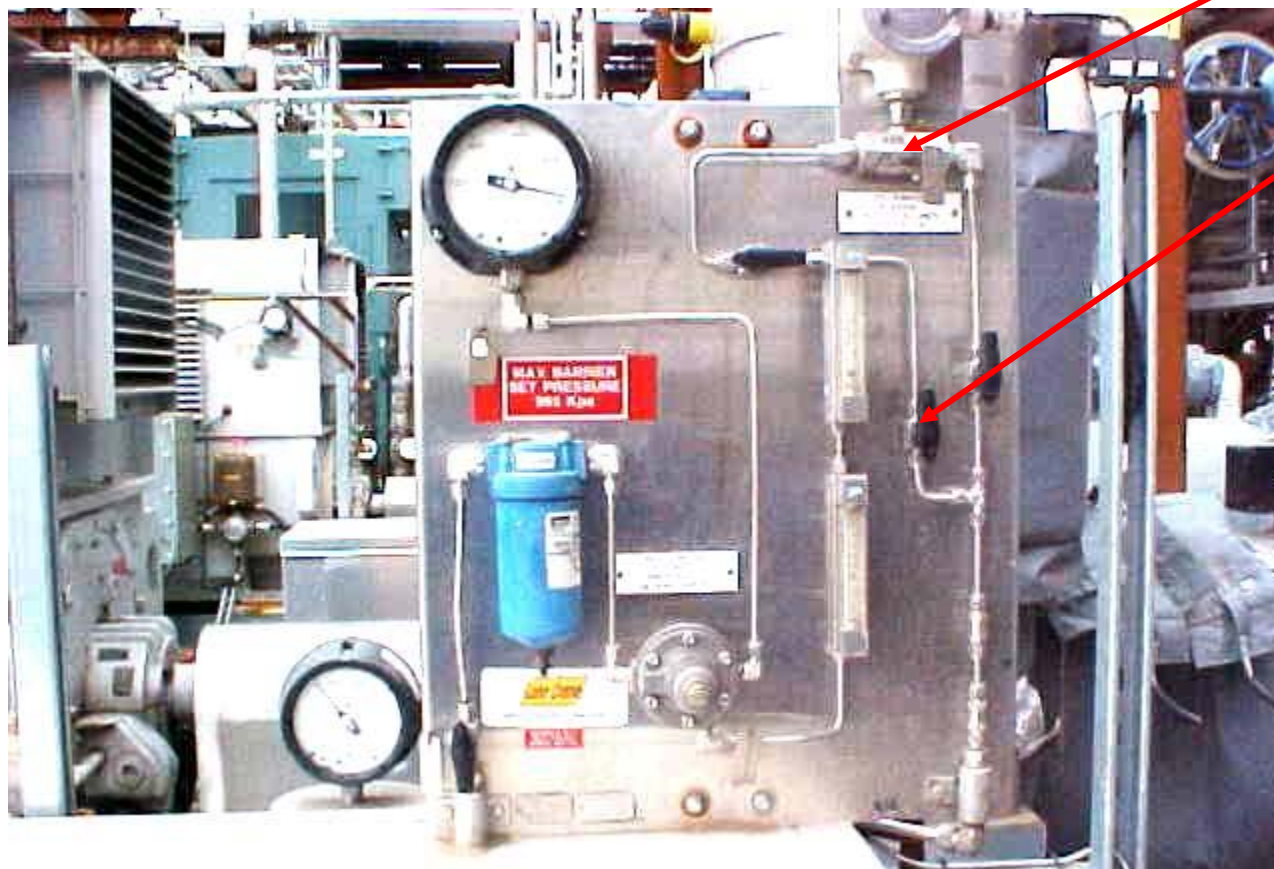
Nitrogen Flow Measuring Turbine Meter Commissioning Issues

Recommendation for Success:

- Use modified seal panel tubing with bypass line.
- Explore alternate flow meter that can withstand the minimum to maximum pipe flow, within acceptable accuracy and reliability.



Nitrogen Gas Panel



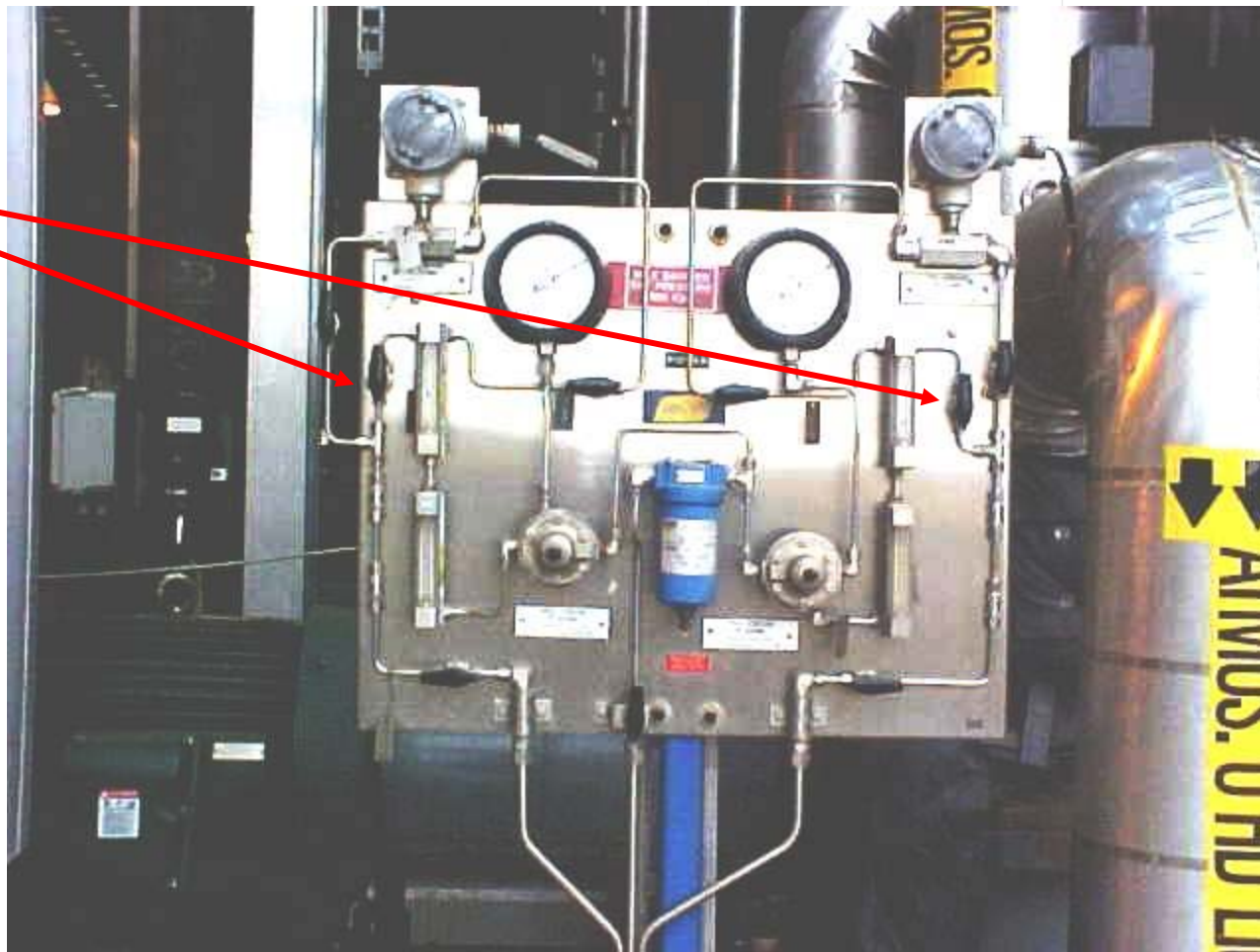
Flow Turbine meter

Turbine
meter by-
pass line
with
isolation
valve

Gas control Panel with single flow turbine meter for over hung pumps

Nitrogen Gas Panel

Turbine meter
by-pass line
with isolation
valve



Gas control Panel with two flow meters for between bearing pumps

Nitrogen Booster Over-cycling issues

Due to frequent nitrogen supply header pressure swings, the nitrogen boosters (installed to boost plant nitrogen pressure above stuffing box pressure $>700\text{kPa}$) are in continuous operation, causing frequent seal failures.

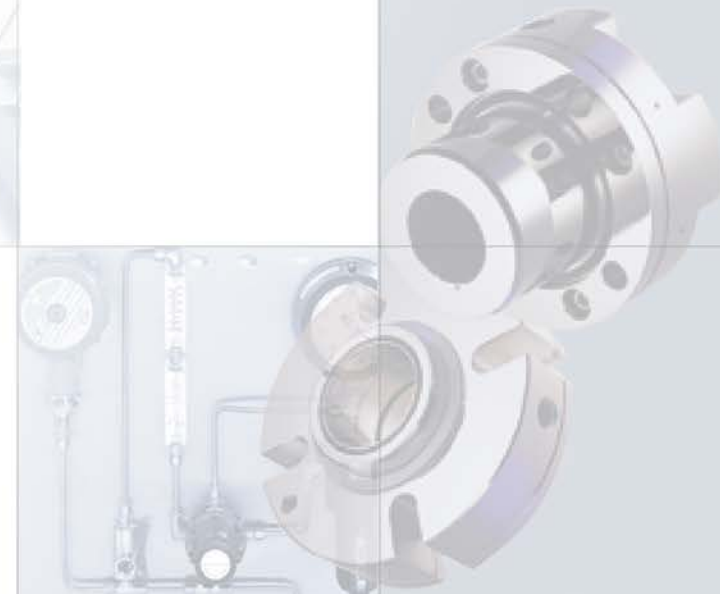
Bone dry nitrogen along with the pipe rust and dirt cause booster rider bands to wear out and fail to develop the required pressure (i.e. 200kPa over stuffing box pressure).



Nitrogen Booster Over-cycling issues

Recommendations for Success:

- Install nitrogen back-up piping system with high pressure nitrogen cylinders.
- Design an auxiliary equipment data sheet in association with seal manufacturer and site rotating equipment engineer to improve booster design with better rider band material to increase reliability.



Nitrogen Booster Over-cycling issues

Additional Panel to
monitor cylinder
supply pressure
with safety valves

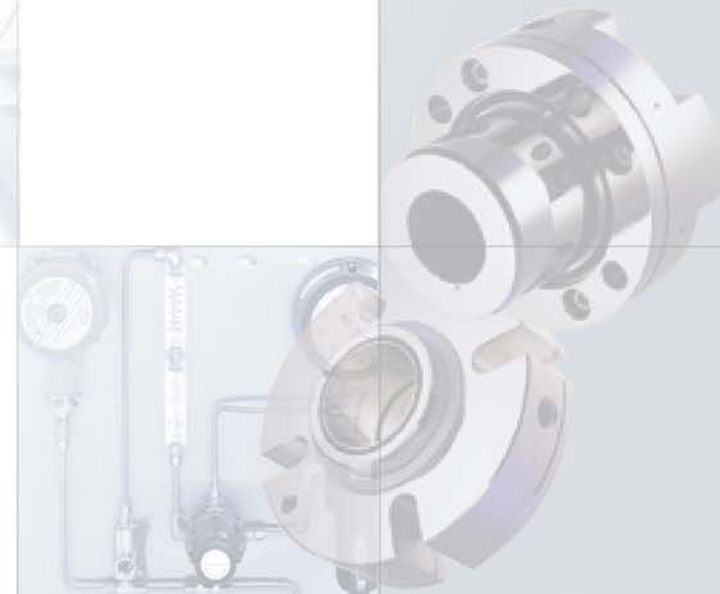
Back-up Nitrogen
Cylinders



Back-up nitrogen cylinder arrangement for DGSeals with boosters

Dry Gas Seal failures exposed to low ambient temperatures

Cold start(s) of pump caused the O-rings (Fluorelastomer & Perfluorelastomer designed for -7C) to seize and the seal to hang up, leading to seal leakage and excess nitrogen flow rate indicating seal failure.



Dry Gas Seal failures exposed to low ambient temperatures

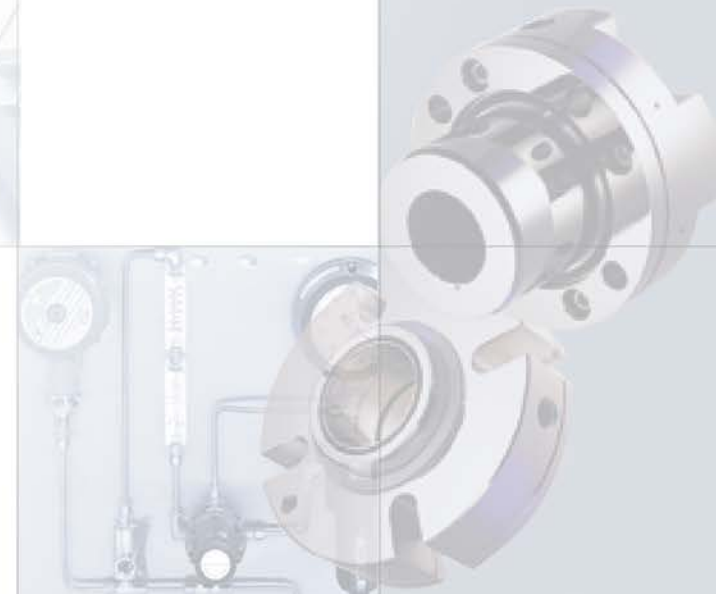
Recommendations for Success:

- To ensure stand-by pump warm-up lines in open condition and bring to operating temperature.
- Prior to starting the pump, ensure the stuffing box flange temperature is above -7°C by filling pump with warm product and installing adequate insulation.



Dry Gas Seals failures in VFD Pumping Application

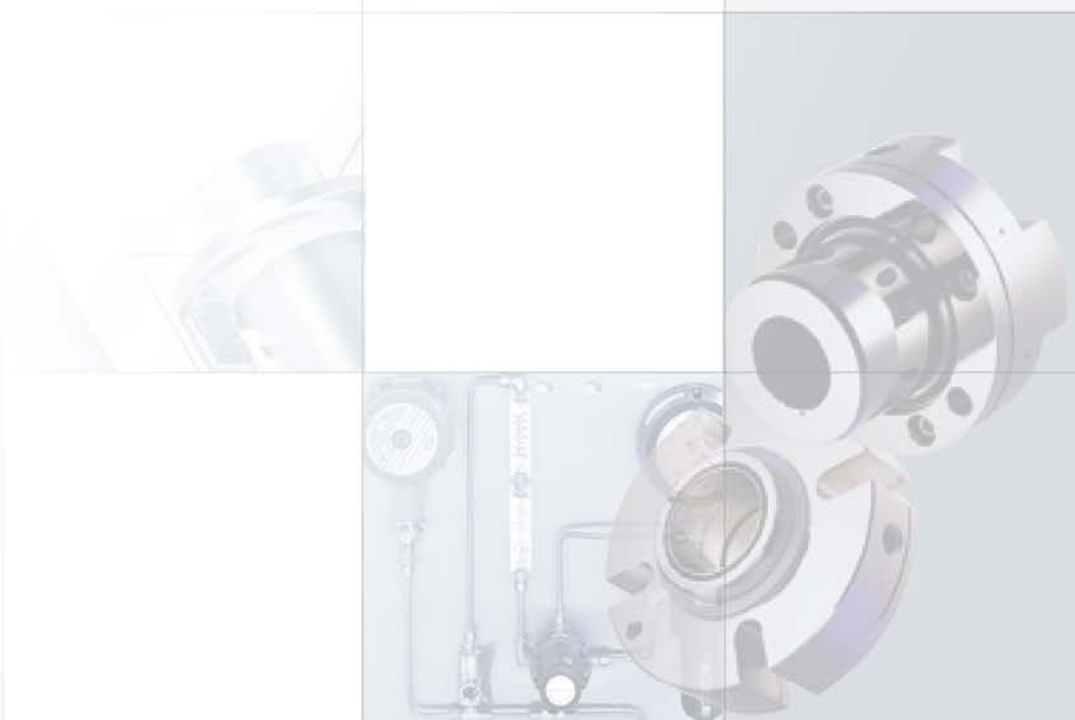
- During initial pump commissioning, the pump VFD was programmed to operate from 1200-2300 RPM.
- At 1200 RPM speed condition, seals made a squealing noise and the seal stuffing box housing slowly got covered with carbon dust.
- Root cause was determined to be inadequate seal face lift-off due to low speed operation.



Dry Gas Seals failures in VFD Pumping Application

Recommendations for Success:

- Program VFD minimum speed at 1550 RPM and maximum speed at 2300 RPM.
- Install RTDs on seal faces to record the seal face temperature and predict seal failures



Dry Gas Seals failures in VFD Pumping Application



John Crane Failure Analysis Report

- *The cavity of the mechanical seal did not show any indication of product.*
- *Other than a massive amount of seal face materials, there was no residue of process fluid inside*

Dry Gas Seals failures in VFD Pumping Application



John Crane Failure Analysis Report

- *The outboard seal faces were virtually destroyed. The silicon carbide mating ring was in several pieces. Half of it was broken down to small debris.*

Dry Gas Seals failures in VFD Pumping Application



John Crane Failure Analysis Report

The inboard carbon primary ring seal face completely worn off.

Dry Gas Seals failures in VFD Pumping Application

John Crane Root Cause Failure Analysis Report

- Severe o-ring degradation on both the stationary and rotating seal heads.
- Temperatures in excess of maximum design temperature (204C) obtained.
- The theory on why the outboard set of seal face failed first, is because they are exposed to the greatest differential pressure (965kPa) and more prominent to make contact with each other when an upset condition has occurred.
- When the seal faces make contact, the face grooves wear off, removing the pressure dam technology designed to lift off the seal faces from one another. The seals remain in contact during dynamic operation until catastrophic failure.
- The installation Resistance Temperature Detection Sensors in the seal gland provides accurate measure of the seal face temperature and alleviates catastrophic seal failure.

Dry Gas Seals failure in Series Pumping Application

- P-26101ABC, P-21133AB, & P-21101AB pumps are in series, the latter of which was installed with Dry Gas Seals.
- Over six months, during tower process upsets, the P-21133AB pumps the liquid through the pump, resulting in a slow roll operation of P-21101A pump(below 500 rpm) due to pressure differential.
- Type 2800 HP Seals or Type 2800 Seals are not designed to operate in slow roll condition.
- As a result, the latter pump experienced 5 seal failures and \$80,000 CAD in spares/maintenance labor cost per failure



Dry Gas Seals failure in Series Pumping Application

Recommendations for Success:

- Replace dry gas seals with double seal, API Plan 54 (stand alone pressurized barrier fluid circulation system).



Dry Gas Seals failure in Vertical In-line pumps



- Typical vertical in-line pumps with stand-by pump arrangement involves one pump in operation and second pump in stand-by mode.
- When pump is not running, the pump is filled with nitrogen through the seal pushing the process liquid out of the pump casing. Starting the pump in this condition will cause pump failures due to dry running
- Continuous run in this mode causes pump seal failures or seizure.

Dry Gas Seals failure in Vertical In-line pumps



Recommendations for Success:

Install vent lines from pump casing of vertical pumps to an elevated point on the suction side of the pump or safe location.

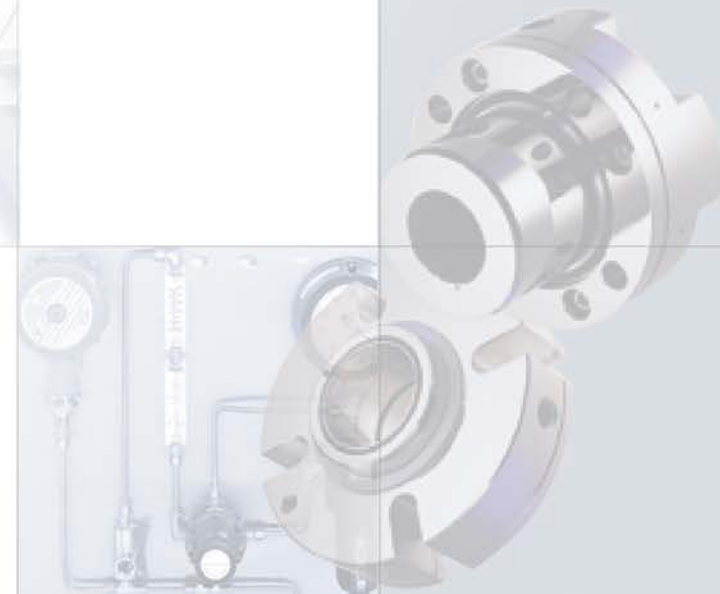
P-21113 A/B RCFA Success Story

Pump: Flowserve DSHF 12x16x22

Process fluid: Hydrocarbon (26 ppm H₂S)

Mechanical Seal: John Crane 4.125" Type 2800 Dry Gas Seal

- January 2003 to March 2004 total 7 seal failures on both A & B pumps.
- MTBR approximately 3 months
- All seal failures indicated severe face contact



P-21113 A/B RCFA Success Story

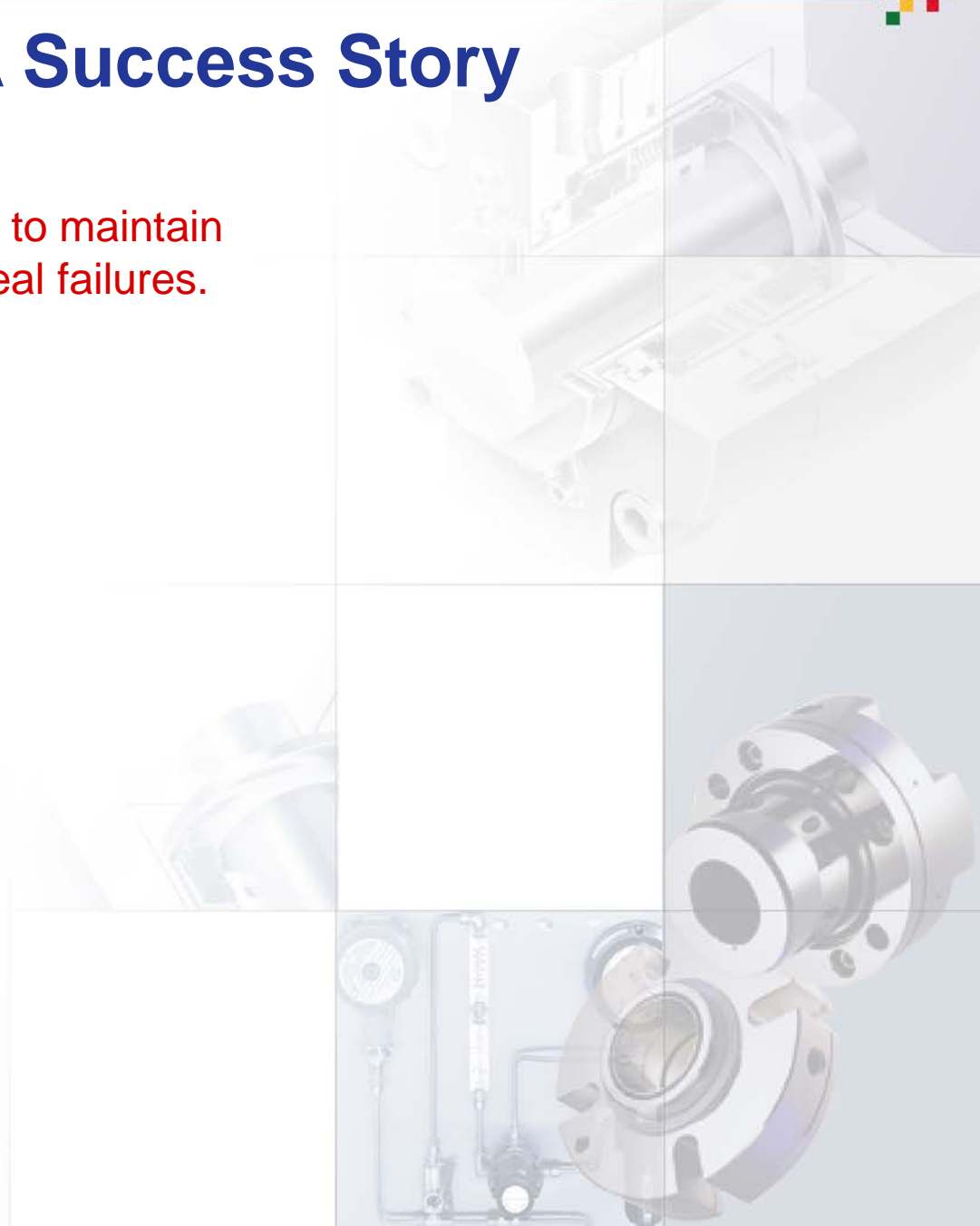
- Seal failures were assumed to be directly related to insufficient rotational speeds.
- Seal temperatures when face contact occurs were identified with a Resistance Temperature Detection Sensors.
- Any temperature rise across seal faces higher than 15C above process temperature, indicates seal face in physical contact.
- Trending seal face temperature identified seal face contact did not occur until pump flows were at minimum levels.



P-21113 A/B RCFA Success Story

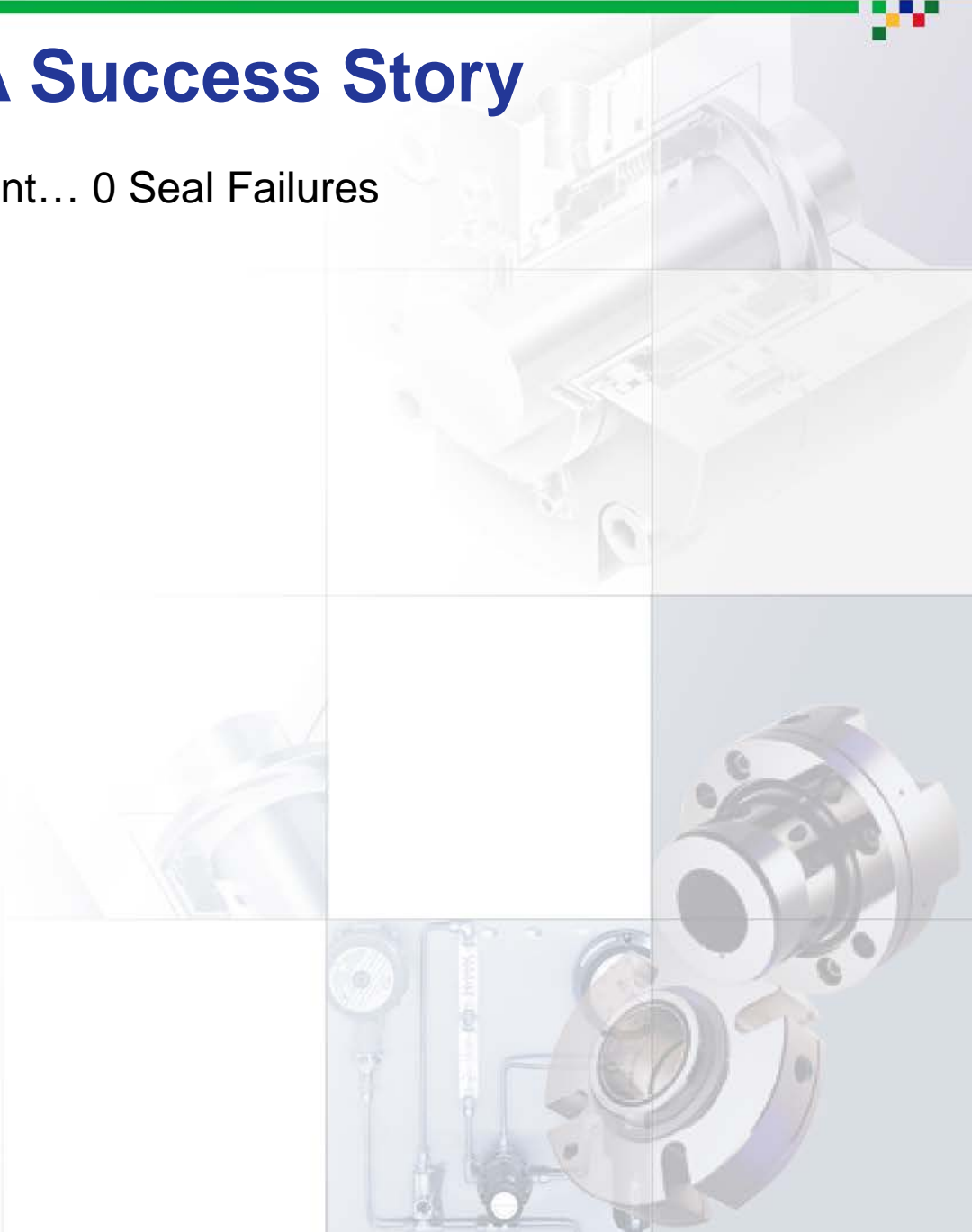
Recommendations for Success:

- New procedure and guidelines to maintain stable flow to avoid frequent seal failures.



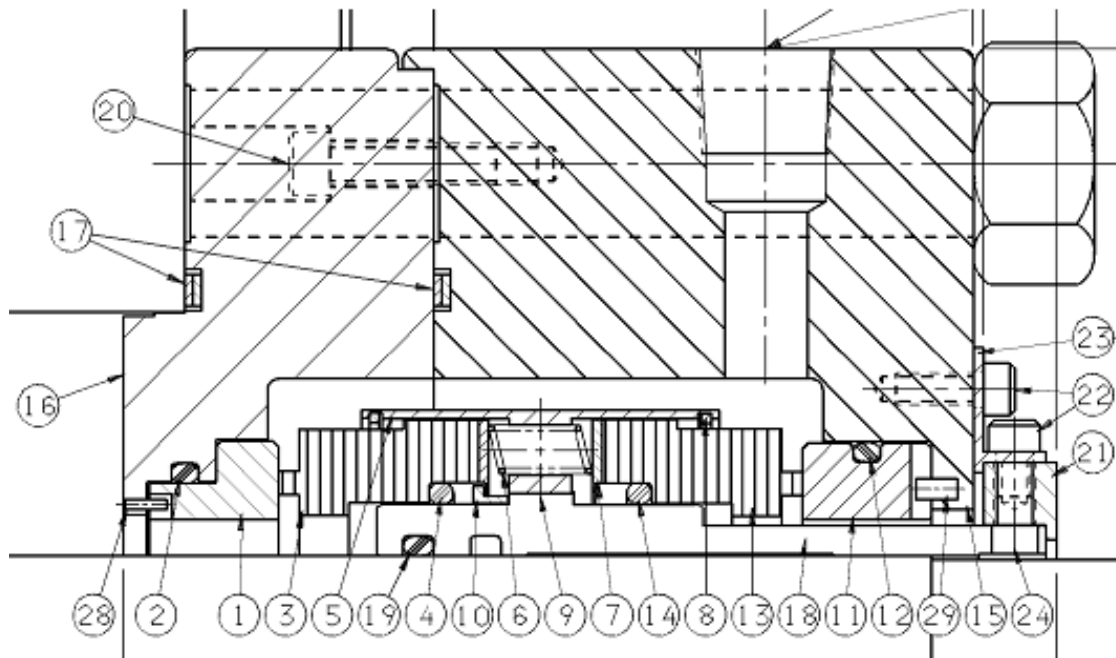
P-21113 A/B RCFA Success Story

March 2004 to Current... 0 Seal Failures



Seal Failure Analysis Report - P-21113A/B

Seal Type & Size : 2800 Double Cartridge, 3.5 seal head



Failure Analysis Report #1



Seal Failure Analysis Report - P-21113A/B



Carbon dust contamination inside seal chamber due to dynamic face contact with silicon carbide seal face

Seal Failure Analysis Report - P-21113A/B



Seal elastomers damaged due to excessive heat generation from dynamic face contact

Seal Failure Analysis Report - P-21113A/B



Inboard carbon primary ring deep grooves



Outboard Mating Ring – Silicon Carbide severe abrasive wear

Still looking for solutions !

- 1 year trial run test with alternate nitrogen booster manufacturer. Developing specifications with better material based on field operating experience.
- Vertical in-line pumps not in continuous service during start-up resulted in nitrogen accumulation causing air lock and seals hung-up and pump not producing the required flow.
- The initiation of seal deterioration
 - Indicators/failure criteria (i.e. flow and seal face temperature by installing Resistance Temperature Detection Sensors)
 - Early detection methods